US Army Corps
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Missouri River Division

Analysis of Channel Degradation and Bank Erosion in the Lower Kansas River

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EXECUTIVE SUMMARY

I. INTRODUCTION

Over the past few decades, severe bed degradation, channel widening, and bank erosion have occurred in the lower Kansas River. The approximately 52-mile reach between the confluence of the Kansas and Missouri Rivers and the Bowersock Dam at Lawrence, Kansas, shows the most noticeable activity, although additional problem areas occur in the upstream reaches. Several natural and man-induced factors may have influenced the morphology of the river and could be responsible for the apparent increase in channel activity during this time period. These factors include:

1. Changes in the stage-discharge relation on the Missouri River at Kansas City due to the Missouri River navigation channel and bank stabilization project. This project has been in progress since the early 1900's. It includes the Liberty Bend cutoff located approximately 14.5 miles downstream of the mouth of the Kansas River which was made in 1949.

2. Construction and operation of a number of reservoirs on tributaries of the Kansas River beginning in 1946.

3. Extraction of significant quantities of sand and gravel from the river channel, particularly in the reach from approximately 8 to 22 miles above the mouth.

4. Other activities, including construction of Bowersock Dam at Lawrence, the Johnson County weir, approximately 15 miles upstream of the mouth, and various other bank and channel protection measures throughout the river reach, including riprap revetments, levees, dikes, and jetties.

II. PURPOSE

The purpose of this project was to investigate the changes that have occurred in the lower Kansas River and to determine their probable causes. In conducting the study, the above factors were investigated to evaluate the amount of increased channel activity attributable to each, recognizing that natural alluvial channels are dynamic systems which will exhibit changes regardless of the influence of man's activities.

III. METHODOLOGY

The analysis procedure can be divided into four parts: (1) a geologic and physiographic description of the river system; (2) an initial qualitative geomorphic analysis; (3) a quantitative geomorphic analysis in which the results of the qualitative analysis are quantified and verified to the extent possible; and (4) the application of a continuity-based sediment-routing computer model.

The geologic and physiographic description of the system was developed from a review of pertinent literature and field observations. Two methods were used in performing the qualitative geomorphic analyses. The first method indentifies past changes in the river system due to natural and man-induced events and then extrapolates these observations to predict the response of the river to varying conditions based upon similarity to the observed changes. This method relies upon historical information contained in aerial photographs, previous reports, maps, stream gaging records, personal observation, and design or as-built plans for bridges, weirs, and other structures constructed near the river. A considerable amount of this type of information exists for the Kansas River. The second method utilizes the principles of geomorphology, hydraulics, erosion and sedimentation to identify the potential impacts due to various activities. By using a combination of these methods, it is possible to establish, within reasonable limits, the probable response of the system to a variety of scenarios. Although the exact magnitude of changes cannot be evaluated, the type and general direction of changes can be established, providing an excellent assessment of the factors which have created the current condition of the river.

The quantitative geomorphic analysis consisted of the following:

1. A hydraulic analysis of the Kansas River using the Corps of Engineers (COE) HEC-2 model with available cross sections and calibration data.

2. Calibration of sediment transport relations along the Kansas River.

3. An incipient-motion analysis using Shield's criteria.

4. Computation of average annual sediment loads based upon computed flow-duration curves and the transport relations from Number 2.

5. Analysis of reservoir-induced depth fluctuations on bank stability.

6. Analysis of the headcutting zone near RM 22 to RM 23.

The continuity model was applied to all but the lower 12 miles of the Kansas River. The hydraulics, and consequently the sediment transport rates, of the lower 12 miles of the river are a function of stage on the Missouri River as well as discharge on the Kansas River. Because of this, sediment transport rates within this reach are highly variable and difficult to accurately model. Furthermore, the qualitative geomorphic analysis indicates that this reach is relatively stable, although it has undergone historic cycles of aggradation during normal flows followed by degradation or scouring of the deposited material by flood discharges.

Five conditions were modeled. For four of these conditions, a synthesized hydrologic record supplied by the Corps of Engineers (COE) was used. Two variations of this record were used in the simulation. One variation was developed by applying the reservoir operating rules to the pre-reservoir flow portion of the record in order to obtain a synthesized 33-year daily-discharge record of regulated flows. The second variation of the synthesized flow record had the effects of the reservoirs removed from the post-reservoir flows in order to create a 33-year daily-discharge record of unregulated flows. The five conditions modeled were:

1. Model verification using the USGS recorded discharge record for 1964 to 1980 and the actual gravel extraction rates from state records. Agreement between computed and observed values of channel aggradation/degradation was very good.

2. No-reservoirs, no-dredging condition using the synthesized hydrology.

3. No-reservoir, with-dredging condition using the synthesized hydrology and the sand and gravel extraction quantities for the period 1940 to 1973.

4. With-reservoirs, no-dredging condition using the synthesized hydrology.

5. With-reservoirs, with-dredging condition using the synthesized hydrology and the sand and gravel extraction quantities for the period 1940 to 1973.

IV. RESULTS

The results of these analyses indicate the following conclusions:

1. Operation of the federal reservoirs has changed the flow duration characteristics of the Kansas River. This has resulted in reduction in the amount of bed material carried by the system (approximately 30 to 40 percent) on an annual basis. On a reach-by-reach basis, the reduction in bed-material transport due to operation of federal reservoirs varies. In

general, the aggradational tendency of some reaches increased while the degradational tendency in other reaches is somewhat dampened. This process helps offset the degradational impacts due to dredging in Reaches 2 and 11 (RM 147.5 to 121.5 and RM 24.0 to 15.1, respectively). The aggradation tendency in the Topeka area (Reach 5, RM 80.6 to 101.0) is reduced by the operation of the reservoirs. Although it still aggrades for the with-reservoir condition, the amount of aggradation is less, indicating a greater impact due to extraction of material through sand and gravel dredging. Changes in the flow duration have also had some impact on the sediment sizes being transported by the system. Incipient-motion analysis indicates that the maximum size that can be transported has been increased slightly for medium flows (those equaled or exceeded approximately 2 to 20 percent of the time). For higher flows, the maximum sizes that can be transported have been reduced by approximately 50 percent.

Rapid fluctuations in stage can decrease bank stability through its effect on pore water pressure within the banks. Operation of the federal reservoirs has not significantly changed the stage fluctuations in the Kansas River, and therefore this factor has little or no impact on the stability of the channel banks. Larger duration of two-thirds to three-quarters bankfull flows, on the other hand, may have increased the tendency for bank erosion, although this is probably compensated for by reduced bank erosion due to attentuation of high flows.

2. Sand and gravel dredging appears to be the primary cause of the bank erosion and channel widening in the lower 30 miles of the Kansas River. Significant quantities of material have been removed from the channel bed in this reach during the past 50 to 75 years. Between 1952 and 1976, approximately 49.3 million tons of material were dredged between Turner Bridge and Bonner Springs, which corresponds to an average thickness of approximately 15 feet within the main channel. Sediment continuity indicates a direct relationship between the dredging activity and channel degradation and bank erosion. As evidenced by the approximately 8 to 15 feet of degradation and 150 feet of channel widening between Turner Bridge and Bonner Springs, available data show areas within the lower Kansas River which have undergone the most severe degradation are the same locations where extensive dredging has taken place.

   Sand and gravel dredging impacts tend to relatively localized, although removal of large quantities of material over a large area can result in lowering of the bed and an increase in the channel gradient at the upstream end of the dredge area. This increased gradient causes a local increase in the transport capacity and may produce a headcut that will translate through the system in an upstream direction, reducing the channel slope until a natural or man-made control is encountered. Available data indicate this this has, in fact, happened near RM 22.

   Artifical deepening (and/or widening) of the channel due to dredging also creates a ponding effect which traps the coarse material and may induce further scour downstream of the dredge areas. This factor does not appear to be significant for this system, however.

3. <u>Lowering of the base level of the Missouri River</u> has had an insignificant impact on the degradation and bank erosion in the lower Kansas River since at least the early 1950's. Sufficient data are not available to evaluate this impact with any degree of certainty prior to that time. Historical thalweg profiles between the mouth and Turner Bridge indicate significant degradation between 1931 and 1951. It is thought that the majority of this occurred during the 1951 flood. Since 1951, the channel bed within this reach has actually aggraded. Additionally, the presence of the geologic control at RM 12.0, which was documented as early as 1956, and the Johnson County weir, constructed in 1967, will prevent further lowering of the Missouri River base level from translating upstream in the Kansas River.

4. <u>Major man-made structures</u> that affect the morphology of the Kansas River <u>include Bowersock Dam and</u> Johnson County weir. Both of these structures act to stabilize the channel by fixing the channel-bed elevations. Both structures produce some backwater effect at lower discharges, which results in trapping of the bed load and a portion of the suspended load. At higher discharges, the hydraulic conditions are such that the bed-material load is not significantly altered by the presence of the structures. Their primary impact is to fix the elevation of the channel bed, preventing further degradation.

   Other man-made structures which have a smaller impact are the bank protection measures which have been installed at numerous points throughout the system. These measures have limited the lateral migration potential of the river at specific locations and have slightly reduced the available supply of bank material. Due to their limited extent and the high percentage of unprotected bank, however, their overall impact on the degradation and bank erosion is minor.

In addition to the four factors discussed above, the impact of the 1951 flood on the morphology of the system should not be overlooked. This extremely large event dramatically altered the system, causing severe degradation and bank erosion. Based upon available information, the post-flood channel was straighter and the cross-sectional area much larger than was the case before the flood. Since that event (and partially as a result of changed flow regime due to the construction of the federal reservoirs), the channel has been steadily changing as it regains a quasi-equilibrium condition consistent with the present hydrologic regime. Many of the observed trends in the past three decades, including apparent accretion on the inside of the bends and formation of vegetated islands where unstable sand bars previously existed, can be attributed to this factor.